DEVELOPMENT OF AN IMPROVED DOSIMETRY SYSTEM FOR THE WORKERS AT THE MAYAK PRODUCTION ASSOCIATION

PROJECT 2.4

PROGRESS REPORT

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Submitted to the Office of International Health Programs, U.S. Department of Energy for the US-Russia Joint Coordinating Committee on Radiation Effects Research

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PROGRESS REPORT, October 98 through March 15, 1999
(Additions/changes since last report presented in *italics*)

I. Summary of Work

We are pleased to report some substantial progress in some areas and some re-focusing and revised leadership roles in several other areas. The most significant of our milestones for the first half of FY-99 is the delivery of the uncorrected external and internal dosimetry data. This is due April 1, 1999 and there appear to be no obstacles in meeting this first deadline. Also initiated during FY-99 is the entering of more extensive worker histories into the database at Mayak. This work is also progressing on schedule.

At the recent Salt Lake City Workshop, there were several significant changes/additions made to the research plan. These include: a) A change in leadership from the Russian to the U.S. team on the determination of the uncertainties for internal dose calculations. This change was acceptable to all parties. b) A consensus for the need to develop some reasonable guidelines for the use of the dosimetry data by other investigators to protect the intellectual rights of the investigators and to assure that the dosimetry data are appropriately used. The U.S. team will take the lead in developing these guidelines. c) We now have established some firm deadlines for the production of several manuscripts describing these studies. d) Studies on the size distribution of aerosol particles have been planned. These data will be important in the modeling studies and the development of new models that will provide improved dosimetry data.

Members of the Internal Advisory Committee whose expertise related to internal dosimetry participated in the Salt Lake City workshop and are advising and assisting us on the construction of improved dosimetric models. Those members of the Advisory Committee involved with external dosimetry are being consulted independently as these studies progress, but will be invited to work with the Russian teams when arrangements can be made for them to visit the United States.

II. Milestones and Deliverables Accomplished During the Reporting Period

A. Management Approach

This is a multi-disciplinary, multi-task, and operationally and scientifically complex project. The overall management of this project must remain flexible to accommodate the changing needs and requirements to fulfill the project goals. The management approach from the new US team may be summarized as:

- Budgetary constraints. The project must function within an austere budget. Clearly, there must be careful allocation of resources that fit the priority needs.
- Flexibility. We anticipate that the scientific and technical needs of this project will change as the program progresses. To ensure the necessary flexibility and optimal allocation of resources, all investigators understand that there will be no "entitlements" or "tenure" into the projects Investigators will be included only to perform specific scientific or operational objectives.
- Open communication. Project 2.4 is central to all projects in Direction 2. For this reason, open and frequent communication among all projects, including the Russian collaborators, must be accomplished and maintained.
- Consultants and advisors. We will use consultants and advisors extensively in this project. A more formal Internal Advisory Group will be utilized to review all of the research plans and programs.
- Student involvement: The U.S. Team functions within a University environment and students will be used extensively in this work. This includes some undergraduate students, but primarily Masters-level or Doctoral-candidate students.
- Faculty appointments for Russian investigators: It is our desire to create a true academic collaboration with our Russian colleagues and investigators. *Three members of the Russian team have received appointments as Adjunct Professors at the University of Utah. These renewable appointments were approved in September and are effective through June 31, 1999.*
- Departmental resources: To supplement the funding from the USDOE., some institutional support is being contributed to the conduct of this project. Mostly this would be to support the student research efforts in this project and include direct institutional support and some scholarship funds. *Institutional funding partially supported the Dosimetry and Modeling Workshop that was held in Salt Lake City, February 22 and 23, 1999.*

B. General Leadership Roles for the U.S. and Russian Teams

A joint meeting with the new Project 2.4 team leaders and the Russian team was held in Washington, DC in April of 1998. At this time, the primary and secondary leadership roles of the general dosimetry tasks were determined. We emphasize that all tasks are to be conducted jointed, but this identified which group would take the leadership or primary role in implementing these tasks. *Recently, these tasks were reviewed with the FIB-1 team and there was the decision to change the role of the U.S. investigators on the determination of uncertainties in internal dosimetry. The U.S. team* *will now lead this effort. In addition, it was determined that the preparation of the existing FIB-1 model for publication would be coordinated with the Project 2.1 team. This was collaboration was already established in the existing task list.*

Tasks	Primary Role	Secondary Role
External dosimetry		
Gamma, beta, neutron doses	Russia	U.S.
Organ dose calculations	U.S.	Russia
Occupations histories	Russia	U.S.
QA/QC		Both
Internal dosimetry		
Internal model (FIB-1)	Russia	U.S. (2.4, 2.1)
New biokinetic model	Both	
Dose uncertainties	*U.S.*	*Russia*
Occupational histories	Russia	U.S.
Common identifier	Russia	U.S.
QA/QC	U.S.	Russia

C. Data Access Agreement

A revised data access agreement was prepared and delivered to both the FIB-1 and Mayak investigators at the E.C. meeting held in Germany in October of 1999. Subsequently, a minor revision was made. To date, this data access agreement has not been signed by all parties.

D. QA/QC

In the last report, we included an extensive QA/QC evaluation that was done last fall. This report was included in the FY-98 summary report. This report was delivered to the Project 2.3 investigators and a subsequent report of their findings were delivered to the Project 2.4 team in December, 1998 . This proved to be an invaluable exercise and illustrated some weaknesses and strengths of the current databases and the transfer of information. The QA/QC procedure that has been developed will continue to be employed, particularly during FY-99 to ensure the accuracy of the dosimetry data being transferred and used by the epidemionlogists.

E. Development of internal guidelines for the use of dosimetry data by other investigators.

At the Salt Lake City meeting, the need for the development of guidelines for the responsible and ethical use of the dosimetry data by other investigators was discussed. Members of the Project 2.4 team are concerned that the data has the potential to be used inappropriately, including the use of obsolete data. There was also concern that the intellectual rights of the investigators who generated the data are appropriately acknowledged and recognized in publications derived from these data. In general, similar guidelines have been adopted by most international scientific bodies and by major, peer-reviewed journals. In addition, similar guidelines have been developed by other organizations, including the U.S. Department of Energy, for various data sets

It was agreed that the U.S. team would draft or propose a set of guidelines, possibly even identical to some already accepted by other international bodies. These guidelines would be discussed among the Project 2.4 team and then presented and discussed with the other investigators in Direction 2 or involved with J.C.C.R.E.R. projects.

F. Internal Dosimetry

Progress on Original Tasks

Task 1. Compile all bioassay data (measurements of radionuclides in urine and feces) and make these data available for microfilming at FIB-1. (Menshikh)

Status: Completed during FY-98.

Task 2. Conduct initial meeting with Project 2.2 and 2.3 scientists to establish and maintain routine scheduled contact and to determine additional needs. (Khokhryakov, Menshikh, U.S. Team, Project 2.2 & 2.3)

Status: *The initial coordination meetings have been conducted. In addition, there were additional coordination meetings that are summarized at the end of this report. We expect additional meetings, including on site in Russia, to be conducted during the remainder of FY-99.*

Task 3. Design the structure and format for the final computerized data base to be established for the internal dosimetry part of Project 2.4. This will include a statement of what doses (and associated uncertainty) will be calculated for what organs over what time periods. (Khokhryakov, Menshikh, Romanov, Vostrotin. U.S. Team)

Status: The format of the database at FIB-1 has been established and there will be no changes until the first complete set of internal dose information is provided in April, 1999.

Task 4. Determine that the proposed structure and format of the internal and external dosimetry data bases at FIB-1 and Mayak PA will be compatible and consistent. Also consult with investigators from Projects 2.2 and 2.3 to ensure that their dosimetry data needs will be fulfilled insofar as possible by the proposed structure and format envisaged as a result of Task 4. (Khokhryakov, Menshikh, U.S. Team, Vasilenko, Fevralev)

Status: This issue was explored during the QA/QC exercise during the September, 1998 visit. While the structure and format of the databases differs, individual records could be cross-checked at both locations. The initial dosimetry needs for Projects 2.2 and 2.3, in terms of monthly and annual doses, are being entered into the appropriate databases. *In addition, a meeting among the FIB-1 investigators on database issues was held in December, 1999 The U.S. desires to have a database meeting with FIB-1 and Mayak investigators in May, 1999.*

Task 5. Ensure that all bioassay data necessary for Projects 2.3 and 2.4 are entered into the primary computerized data base. (Menshikh)

Status: in progress.

Task 6. Develop algorithms for dose computations in accordance with the needs of Projects 2.2 and 2.3. For Project 2.3 this includes monthly doses for lung, liver, bone and bone marrow. (Menshikh, Khokhryakov, Romanov, Aladova, U.S. Team)

Status: The initial internal dose calculations will be delivered in April, 1999, using the current FIB-1 biokinetic model and includes doses to various organs. This task is on schedule.

Task 7. Provide interim internal doses as needed for Projects 2.2 and 2.3 using the existing FIB-1 Pu metabolism and dosimetry model. (Menshikh, Khokhryakov, Romanov, Aladova, U.S. Team)

Status: This task in on schedule and will be provided by April, 1999.

Task 8. Conduct a comparative analysis of the most likely intake scenarios at work sites. (Suslova, Aladova, Vostrotin, with Mayak PA and U.S. Team)

Status: The occupational histories and information is also necessary to reconstruct gamma, neutron and beta doses. Thus this effort will be coordinated between the Mayak PA and FIB-1 and facilitated by the U.S. team. *Beginning in FY-99, the worker histories at Mayak are being entered into the database.*

Task 9. Implement a Quality-Assurance (QA) and Quality-Control (QC) procedure for the entry of the bioassay data into the computerized database. (Suslova, Menshikh, Aladova, U.S. Team)

Status: An internal QA/QC procedure has been implemented that includes double entry in the data bases. *Additionally, records were reviewed during the initial QA/QC audit in September, 1998 and a report was issued.*

Task 10. Modernize the existing biokinetic model of industrial Pu compounds and develop an improved dose-calculation method based on the changes in the modernized model. Make appropriate changes in the algorithms used for dose calculation. (Khokhryakov, Menshikh, Romanov, Vostrotin, U. S. Teams on Projects 2.4 and 2.1)

Status: To begin this modernization of the existing biokinetic model the 2.4 investigators agreed to do some initial comparisons with the existing FIB-model and the current ICRP model. Data specific to this modernization is being determined in conjunction with task 17. *Some of the recent data on this effort was presented at the Salt Lake City workshop (February, 1999). We expect this effort to accelerate after the delivery of the uncorrected doses in April, 1999.*

Task 11. Perform analysis of errors and systematic biases and evaluate uncertainties of dosimetric parameters used for internal dose calculations; evaluate any possible correlations among the sources of uncertainty. (U.S. Team, Khokhryakov, Suslova, Menshikh, Aladova)

Status: *The U.S. team will now lead this effort, as agreed in Salt Lake City, February 1999.* We have agreed that we would first distinguish possible system, measurement and other sources of errors. We would then use the uncertainties methodology established for the Hanford dose reconstruction models and developed by E. Gilbert (Project 2.2). Furthermore, we will also explore quantifying the uncertainties using perturbation methods. Uncertainty analyses will also require close coordination with the specific needs of the investigators in Projects 2.2 and 2.3. *An outline of the approach that was presented and discussed by the investigators in Salt Lake City, February, 1999, is enclosed as an attachment to this document.*

Task 12. Prepare manuscripts on internal dosimetry models (FIB-1 model) used for the initial internal dosimetry data. Additional manuscripts may include validation of the model (or corrections to the model) based on extrapolation of bioassay data with autopsy data. Khokhryakov, Suslova, Menshikh, Romanov, Chernikov, U.S. Teams for Project 2.4 and 2.1)

Status: *The initial manuscript of the FIB-1 model will be authors by Dr. Kkokhryakov and the other FIB-1 investigators. They will be assisted by investigators on*

Project 2.1 and, if invited, by the project 2.4 U.S. team. However, the FIB-1 investigators have agreed to deliver a first version of the manuscript by May, 1999. This draft will be reviewed by the Project 2.4 team during May in Ozyorsk so that planning can commence for additional comparison manuscripts and development of improved dose estimates.

Task 13. Provide finalized monthly dose values and associated uncertainties to Project 2.3. In anticipation of this, provide a rigorous quality assurance assessment of the data base. (Menshikh, U.S. Team)

Status: *The dose uncertainty issues will now be lead by the U.S. team. An initial method to do this has been developed (basic outline enclosed as an attachment). This effort accelerate in May, 1999 after the delivery of the complete set of uncorrected doses in April, 1999 and the review of the first draft of the current FIB-1 model manuscript.*

Task 14. Provide final internal organ-dose values and associated uncertainties to Project 2.2. Values will be of annual doses up to the current time or for time of death. Methods of extrapolating doses into the future will also be provided. In anticipation of this, provide a rigorous quality-assurance assessment of the data base to be provided. (Menshikh, U.S. Team)

Status: *The corrected dose project will begin after the April delivery of the uncorrected doses. Methods of extrapolation are being discussed and include the extensive use of worker histories that are now being entered into the Mayak database.*

Task 15. Research the feasibility of using existing whole body counter screening data for future dose-assessment purposes. (Chernikov, U.S. Teams on Projects 2.4 and 2.1)

Status: It was agreed that this is a very worthwhile task, but will be initiated after the installation of the new whole body counter (WBC) donated by 1.1. Construction has begun for the installation of the new WBC at FIB -1. Preliminary evaluations have been done using two existing WBC for reproducibility and accuracy. A better phantom is also being sought after. This effort will also be coordinated with investigators from 2.1 and 1.1.

Task 16. Conduct studies on dispersion of aerosols in workplaces that have not yet been investigated adequately. (Khokhryakov, Aladova, U.S. Team)

Status: *Some of the "transportability" issues have been previously done under project 2.1. However, some new studies were designed by the Project 2.4 team to determine the size of the particles. A compact device will be designed and engineered at the University of Utah that is capable of near-isokinetic extraction of airborne particulates. Its purpose is to collect sufficient number of* *particulates from different locations on the Mayak site for size and composition determination. The evaluation will include a number of techniques (i.e., SEM, EDX, NIAR etc.) which will be performed at the University of Utah. This will provide interim information untill the cascade impactor is put into service at the Mayak. It as anticipated this device and associated supplies will be available for the May trip to Russia.*

Task 17. Prepare and publish one or more final articles on the results of the dosimetric studies. Work with epidemiologists from Projects 2.2 and 2.3 to prepare joint papers on the results of the dosimetry/epidemiology studies. (Khokhryakov, Menshikh, Suslova, Vostrotin, Chernikov, U.S. Team)

Status: *There are plans for several manuscript on internal dosimetry alone and then in collaboration with investigators from other projects. These include:*

1. *Description of the existing FIB-1 model. Draft due upon visit in May.*
2. *Comparison of dosimetry models.*
3. *Bone tumors, with Project 2.2.*
4. *Liver tumors, with Project 2.2.*
5. *Acute radiation syndrome, with Project 2.3.*

G. External dosimetry

The effort to reconstruct external personal doses are organized under 5 major technical areas. Included under the technical areas are the original tasks accepted by the Scientific Review Group (SRG).

1.0 Reconstruction of Personal Doses from Gamma-Betas Radiation Fields:

1.1 Evaluate the gamma-energy spectrum for each relevant source of personnel exposure. A separate spectrum should be provided for each significant time period. (Vasilenko, Drozhko, Knyazev, Smetanin, US Team)

Status: The evaluation of the gamma-energy spectra at various plant locations is essential for correcting the external dose measurements and for calculations of organ dose levels. The source reconstruction is ongoing and supported by documents that detail the reactor operations (power logs and campaigns) , alterations to plants infrastructure, fuel composition in billets, process of extraction and milling, etc. In addition, limited data exists from area radiation monitors.

1.2 Evaluate the degraded (source modified by shielding, scattering, etc.) gamma-energy spectrum for each relevant work location for personnel exposure. A separate spectrum should be provided for each significant time period. (Vasilenko, Drozhko, Smetanin, US Team)

Status: Generating gamma energy spectra for a number of work locations at reactor, Pu extraction (radiochemistry) , and Pu milling plants are currently under way. It is expected that only a small number of spectra will be needed to effectively represent the gamma-beta radiation fields (Specifically 3 spectra for reactor, 7 spectra for radiochemistry and 4 spectra for Pu milling).

1.3 Develop methodologies for combining data on the energy response of different beta-gamma dosimeters with the degraded spectra to which individual workers were exposed in order to derive a corrected individual "film-badge" dose. (Vasilenko, Knyazev, Smetanin, Alexsandrova, US Team)

Status: This effort involves data being supplied by the GSF (Germany). *Project 2.4 scientists met with the German investigators in November, 1998. A manuscript on these studies is being prepared by the GSF investigators and may be available by June. 1999.*

Experiments are being planned that would investigate the influence of beta particles on the response of the original film badge using a linear accelerator at the University of Utah. Preliminary discussions were initiated with Air Force and Boeing personnel from Little Mountain Facility where the tests exposing the film to beta radiation will be performed. (The University of Utah/CENTER has a cooperative research and development agreement (CRDA) with this facility that allows us the use their specialized equipment and personnel.) The CENTER facility will expose to the dosimetric film known amounts gammas and neutrons to quantify its response. This work is in progress.

1.4 Develop an algorithm for combining data on corrected individual "film-badge" dose with information on the workplace degraded energy spectra to derive work-location values of organ doses. (US Team)

Status: Two gamma spectra, a hard and soft, were provided to see the significance of external exposure to the organs. *A FORTRAN code has been written that calculates the dose to the organs from external exposure to gamma radiation. When the code has undergone verification that it is performing the calculations as intended, the initial results will be forwarded to Vasilenko for review and comment. It is anticipated that a discussion on the methodology and subsequent results will take place in May at Ozersk. At a latter date, dose to the organs due to the presence of neutrons will also be calculated.*

1.5 Develop an algorithm for calculating the uncertainty associated with the corrected values of individual "film-badge" and organ beta-gamma doses. (Alexsandrova. US Team)

Status: *The broad and robust methodology formulated by Lyons for accounting uncertainties though multi-stage processes will be applied. This method goes beyond the current techniques that focus on quantifying uncertainty associated* *with detection. A significant benefit of the technique is that we can incorporate ongoing efforts and results by other investigators (e.g., Dr. Alexsandrova) directly in the quantifying process. Preliminary quantification of uncertainties associated with external doses to the organs will be available for comment in May.*

2.0 Reconstruction of Personal Dose from Neutron Radiation Fields:

2.1 Compile all neutron-flux data and make these data available for microfilming subject to the access needs and authorization. (Vasilenko, Smetanin)

Status: It is our understanding that this either has been completed or is in progress.

2.2 Compile all relevant data on workplace-neutron exposure, including the energy spectrum of neutrons to which exposure likely occurred. (Vasilenko, Drozhko, Knyazev, Smetanin, US Team)

Status: This work is in progress.

2.3 Evaluate the neutron-energy spectrum for each work location of interest as based on accumulated survey data. (Vasilenko, Knyazev, Smetanin, Alexsandrova)

Status: This work is in progress.

2.4 Develop methodologies that will use both data from existing radiation monitors and simulations from neutron transport codes

Status: Two different codes will be used: MCNP and COG. This work is in progress.

2.5 Develop an algorithm for calculating the neutron dose for each individual according to each work location of interest. (Vasilenko, Knyazev, Smetanin, US Team)

Status: *Two methods for reconstruction of neutron fields are being pursued. The first uses post 1980 neutron and gamma dosimetric data for specific locations to correlate characteristic neutron/gamma ratios. Using existing records of operation, personnel, and site attributes, corrective algorithms are being developed to estimate neutron exposure for the earlier years of operations. The second method is to construct reasonable estimates of neutron fields from simple models simulating significant sources using Monte-Carlo transport codes (e.g., MCNP), site descriptions, and work histories. This work is in progress.*

2.6 Develop an algorithm for calculating the uncertainty in individual-neutron dose. (Vasilenko, Knyazev, Smetanin, Alexsandrova, US Team)

Status: *As with the gamma doses, Dr. Alexsandrova is laying the theoretical ground work for estimating different portions of the uncertainty (environmental/occupational practices and circumstances, detection of key exposure parameters and methodology to calculate exposure and dose from neutrons). These newly developed algorithms will be applied directly into the broader Lyons's algorithm (described in attachment 1) for estimating overall uncertainty. This work is in progress.*

3.0 Input Doses in Database and Assure Data Quality:

3.1 Design the structure and format for all primary and secondary computerized data bases to be established for the external dosimetry part of Project 2.4. This will include a statement of what doses (and associated uncertainty) will be calculated for what organs over what time intervals. (Fevralev, US Team)

Status: The structure and format of the primary Mayak database has been established. A Web-server type database format (Sequel) has been implemented. An initial QA/QC on the database and the primary paper records was conducted in September, 1998 at Ozersk. The database contains the monthly and annual doses, as needed by Projects 2.2 and 2.3. The organ dose calculations will be done by the U.S. Team.

3.2 Compare the structure and format of the internal and external dosimetry data bases for consistency and compatibility. (Vasilenko, Fevralev, US Team, Menshikh)

Status: A "common identifier" between the FIB-1 and Mayak databases does not yet exist, although we found that individual records can be tracked between the databases by using a name and employment date.

3.3 Ensure that all external beta-gamma and neutron personnel dosimetry data are entered into a computerized data base. (Vasilenko, Knyazev)

Status: Much of the uncorrected beta-gamma doses have been entered into the various data bases that currently exist (Mayak and FIB-1).

3.4 Provide a rigorous quality-control evaluation of the external beta-gamma and neutron personnel dosimetry database by performing a repeat entry of all data into the database. (Vasilenko, Knyazev, U.S. Team)

Status: A double-entry system for selected cases has been implement to account for data entry errors. A more rigorous QA/QC procedure was implemented that cross-checked the paper records as well as the entries in the multiple databases at both FIB-1 and Mayak PA during the September, 1998 visit to Ozersk. *This effort, lead by the U.S. team, will continue during FY-99.*

3.5 Provide a rigorous quality-assurance and quality-control analysis of all secondary data bases generated. (Knyazev, Fevralev, US Team)

Status: A double-entry system for selected cases will be implemented to account for data entry errors, along with a cross-check of all calculations made for dose corrections. *We also expect that investigators from Projects 2.2 and 2.3 will assist with this effort during this year.*

4.0 Interact with Personnel Associated with Projects 2.2 and 2.3:

4.1 Conduct initial meeting with Projects 2.2 and 2.3 scientists to establish and maintain routine scheduled contact and to determine additional needs. (Vasilenko, Knyazev, US Team)

Status: This has been implemented and will be an on-going process. In addition, we have incorporated the investigators from Project 2.1 into some of the tasks.

4.2 Process all data according to the algorithms developed for Tasks 1 and 2 in order to generate all secondary data bases, which will serve as input to Projects 2.2 and 2.3 (Knyazev, Alexsandrova, Fevralev, US Team)

Status: This work is in progress.

4.3 Deliver interim values of doses and associated uncertainties to Project 2.2 and 2.3 for their selected cohorts. (Vasilenko, Knyazev, Smetanin, Alexsandrova, Fevralev, US Team)

Status: This work is in progress.

4.4 Deliver final values of doses and associated uncertainties for the Project 2.2 and 2.3 cohorts. (Vasilenko, Knyazev, Smetanin, Alexsandrova, Fevralev, US Team)

Status: This work is in progress.

5.0 Generate Publications (Journals and Reports):

5.1 Prepare a manuscript describing the history of neutron-personnel dosimetry in use at the MPA from initial operation through the present time. This report will include data on the energy response of the detectors used, etc. (Glagolenko, Vasilenko, Drozhko, Knyazev, Smetanin, US Team)

Status: Several "Information Reports" on neutron dosimetry have been prepared by the Russian Team. These include "The analysis of methods and organization of individual dosimetric supervision of neutron exposure" and "Development of technique for retrospective estimation of individual neutron doses". These provide excellent background material and information for the further reconstruction of neutron doses and the preparation of associated manuscripts.

5.2 Prepare one or more peer-reviewed papers describing the final external dose results calculated as a result of the external dose part of Project 2.4. (Glagolenko, Vasilenko, Drozhko, Knyazev, Smetanin, Alexsandrova, Fevralev, US Team)

Status: This work is in progress.

5.3 Work with epidemiologists from Projects 2.2 and 2.3 to prepare joint papers on the results of the dosimetry/epidemiology studies. (Glagolenko, Vasilenko, Knyazev, Smetanin, Alexsandrova, Fevralev, US Team)

Status: This work is in progress.

H. Deliverables for Internal and External Dosimetry

Reports:

1. Prepare a report describing the history of gamma and neutron dosimetry in use at Mayak from initial operation through the present time (FY 1999)

2. *Prepare a manuscript on the FIB-1 model used to calculate the uncorrected internal doses used in the April 1, 1999 database. This manuscript will be prepared in collaboration with Dr. Filipy, Principal Investigator of Project 2.1.*

3. Prepare a report describing the assessment of energy spectra for all significant sources of personnel exposure (FY 1999)

4. Report on results of uncertainty analysis (FY 1999.)

5. Prepare a report that describes the algorithm for the calculation of doses to 22 (or more) specific organs (FY 1999)

Corrected Doses and Uncertainties:

6. Provide interim values of doses and associated uncertainties for project 2.2 and 2.3 cohorts (April 1999.)

7. Deliver final values of dose and associated uncertainties for Project s 2.2 and 2.3 cohorts (FY 2000.)

Publications (Journals):

8. Prepare one or more peer-reviewed papers describing the final external dose results for Projects 2.2 and 2.3 (FY 2000)

9. Peer-reviewed publications on the results of the internal doses calculated for Projects 2.2 and 2.3 (FY 2000)

10. Peer-reviewed publication of an updated plutonium metabolism and dosimetry model (FY 2000)

11. Peer-reviewed publication of comparison of results of the updated model to actual results from the analysis of autopsy samples (FY 2000)

III. Other Relevant Information, Including Relevant Trip Reports, Obstacles to Completion or Work Outline in FY Work Proposal, Unexpected Costs, etc.

Since the last report, members of the Project 2.4 team (U.S. and Russian) have been involved with several meetings.

1. Coordination of Research Related to Protracted Ionizing Radiation Exposures from the Mayak Nuclear Facility and the Semipalatinsk Nuclear Testing. This meeting was hosted by the E.C. and included scientists from Europe, Russian and the U.S. Summaries of this meeting were prepared and distributed by the 2.4 team and the subsequently by the organizers of the meeting.

2. Pittsburg meeting: A meeting was held on the coordination of projects 2.3 and 2.4 in Pittsburgh, PA in December, 1998. The project 2.4 team was represented by Scott Miller and the Russian team included four members from the laboratory of Dr. Okladnikova. The entire U.S. project 2.3 team was present. The dosimetry milestones were presented and discussed and the progress to date was evaluated.

3. Washington, D.C. Scientific Review Group (SRG) meeting. Drs. Scott Miller and David Michael Slaughter presented the research plan for project 2.4 to the SRG. Subsequently, their evaluation was received and discussed with both the U.S. and Russian project 2.4 teams.

4. Salt Lake City, UT. Modeling and Dosimetry of Plutonium in Humans. The project 2.4 team (U.S. and Russian) hosted a workshop at the University of Utah. Also involved with the workshop were members of the Project 2.4 Internal Advisory Committee, representatives from Projects 2.1 and 2.3 and others involved in internal dosimetry issues, including several investigators who have D.O.E.-supported feasibility studies. The Russian investigators included Dr. Romanov, Khokhryakov, Suslova, Aladova and Vostrotin.

5. Project 2.4 Internal Advisory Committee. Due to unavoidable scheduling conflicts, the entire Committee has not met in one session, however, those involved with internal dosimetry participated in the the Salt Lake City workshop. Some oral and written material has been received from these advisors. Those advisors involved more with external dosimetry have been consulted independently and they have assisted in the planning and preparations of our work on the various aspects of external dosimetry.

IV. Publications and Preprints

None during this reporting period.

Attachment

A method presented by Louis Lyons in, *Practical Error Analysis for Scientist and Engineers* can be used to estimate the uncertainties for dose reconstruction. The total error or uncertainty is the sum of the differences between the average function and the function with each variable perturbed by the positive and negative standard deviation. The algorithm is:

$$f = f(x_1, \ldots, x_n)$$

$$f_o = f(\bar{x}_1, \ldots, \bar{x}_n$$

$$\bar{x}_1 \pm \sigma_1, \ldots \bar{x}_n \pm \sigma_n$$

$$f_i^+ = f(\bar{x}_1, . x_i + \sigma_i .., \bar{x}_n \quad \text{and} \quad f_i^- = f(\bar{x}_1, . x_i - \sigma_i .., \bar{x}_n$$

$$\sigma_f^{2+} = \sum_{i=1}^{n} (f_o - f_i^+)^2 \quad \text{and} \quad \sigma_f^{2-} = \sum_{i=1}^{n} (f_o - f_i^-)^2$$

The power of the method is that the exact relationship between each variable does not have to be known. For parameters, such as work history, the uncertainty can be estimated by evaluating the dose assuming work locations which generate the highest dose, and the lowest dose. The difference between the high dose, or low dose and the dose from the assumed work location is the uncertainty associated with work location. The algorithm can be implemented in steps, First estimating the uncertainty from the bioassay, then use bioassay uncertainty in addition with the error in the biokinetic model, and intake scenario to estimate the uncertainty in the dose calculation. To simplicity of this method lends itself to broad applications and will be used for both internal and external dosimetry.